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STRUCTURE AND FUNCTION OF AFRICAN FLOODPLAINS

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ABSTRACT

In Africa, floodplains often cover enormous areas. They represent a formidable dry season refuge for the indigenous flora and fauna, but at the same time they have a large potential for the intensive, highly productive agriculture and hydropower production so desperately needed in Africa. The main topographic features of the larger floodplains are reviewed in this paper, along with a general insight into water relations, nutrient dynamics, productivity, species distribution and changes in vegetation induced by present management practice. The question is raised of whether floodplains will survive in the face of development, and a call is made for alternative management strategies.

INTRODUCTION

The inland water habitats of Africa make up about 450,000 km^2 of the continent (Table 1). These habitats include seasonally inundated wetlands, such as swamp forest, peatland, mangrove swamp, inland herbaceous swamp and floodplain, as well as permanent water habitats. The habitat of most concern to us here is the floodplain, which is any region along the course of a river where large seasonal variation in rainfall results in overbank flooding into the surrounding plains. Some of these flooded plains are enormous and are equal in size to the world's larges lakes (Tables 1 & 2). In African floodplains the typical complex vegetation mosaic is most obvious from the air, because they often cover enormous areas, stretching out as far as the eye can see.

In this paper I can only touch briefly on the more important aspects of floodplains. In Africa they defy intensive study for a number of reasons, consequently this paper must be regarded only as a review. I hope it will provide some food for thought and a basis for future research.

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The views and opinions expressed here are strictly those of the author, and in no way should they be interpreted as the views and opinons of the U.S. Government or its official agencies.

Table 1: Large open water habitats in Africa.
Estimated area based on information in Beadle, (1974) and world atlases

Water body	Area (km^2)
Lake Victoria	75,000
Lake Turkana	32,500
Lake Malawi	24,000
Lake Kivu	16,000
Lake Chad	15,000
Lake Tanganyika	8,000
Lake Mobutu	4,700
Lake Edward	2,250
Lake Chilwa	700
Lake George	290
Lake Naivasha	240
Man-made lakes	27,000
Total open water	205,680
Floodplains	245,075
Total water habitats	**450,755**

METHODS

General features

The complexity of the vegetation mosaic seen in tropical floodplains is often the result of physical features relating to local substratum or to the effects of topography, which in turn affect the availability of water and nutrients. Thus in order to understand the basic functions of the floodplain systems we must first look at their general features (see Welcomme, 1979).

Topography

The main topographic features within floodplains are either depressions, i.e. water bodies, or areas raised because of deposition, such as sand bars and mud flats. A typical feature is the levée, which is a raised berm or crest above the floodplain surface. It contains coarse material deposited as the flood flows over the top of the channel bank (Welcomme, 1979). Sutcliffe (1957) described the process whereby a silt-laden river, such as the White Nile, descending an appreciable gradient builds up its own bed and levées until it actually flows at a level above the surrounding floodplain. As the bed slope flattens and flow rates decrease, suspended material is deposited more rapidly, levées decrease in size, and the floodplain widens. Deposition is encouraged by vegetation growing on the levées. A good example is seen on the Cubango River after it leaves Angola and before it enters the Okavango Delta (Fig. 1), also the upper Zaire River with its associated vegetation (Fig. 2). Levées are seen further downstream in the Okavango, and they are also evident where the Nile traverses the Sudan in the Sudd Swamp region. The levées along the Nile River in the Sudd region trap the annual floods in depressions adjacent to the river. These are locally known as "toiches" (Fig. 3) and are fertile, seasonally-flooded habitats which support a wide variety of plant and animal species.

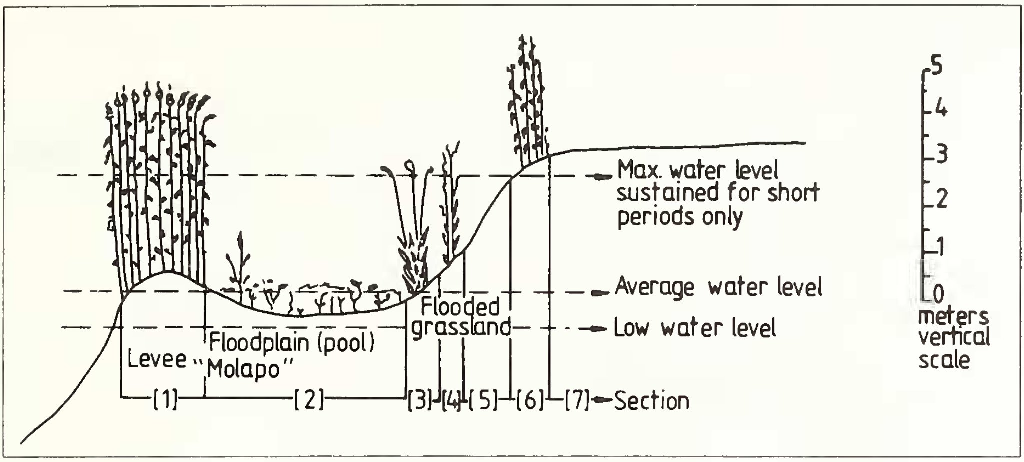

Figure 1. Profile of levée and floodplain (**molapo**) along the Cubango River, Angola (after Smith, 1976)

Table 2: Major African floodplains (after Welcomme, 1979 & Thompson, 1985). Location numbers refer to figure 6

Location number	River system	Region	Area of high water (km²)	Area of low water (km²)	Range of conductance (µs.cm⁻¹)
1	White Nile	Sudd Region, southern Sudan	92,000	10,000	20-500
2	Middle Congo	Zaire and Congo	40,500	-	-
3	Niger	(see text)	25,980	5,980	31-70
4	Chari and	Lake Chad swamps	13,800	-	
	Logone	Yaerés floodplain	5,950	-	41-82
		Sub total	19,750		
5	Okavango	Botswana internal delta	16,000	3,120	-
6	Kenamuke in S. Sudan	Internal delta	13,950	-	-
7	White Volta	Volta Swamps	8,530	-	41-124
	and Oti	in Ghana	4,810	-	-
		Sub total	13,340		
8	Senegal	Main river swamps	4,560	500	72
		Delta	7,970	-	-
		Sub total	12,530		
9	Lualaba	SE Zaire, Kamulando depression in the Upemba Basin	11,800	7,040	141-255
10	Zambezi	Barotse Plains in Zambia	9,000	700	57-126
11	Luapula	Bangweula swamp, Zambia	8,800	-	-
12	Rufiji	Kilombero area in Tanzania	6,650	-	-
13	Kafue	Kafue flats in Zambia	6,000	-	130-320
14	Niger	Niger River floodplain	4,800	1,800	-
15	Luena	Liuwa plains in Zambia	3,500	-	-
16	Benue	Benue floodplain in Nigeria	3,100	1,290	-
17	Kafue	Lukanga swamps N. of Kafue flats, Zambia	2,500	-	-
		Sub total	56,150		
		Total area	**290,200**	**30,430**	

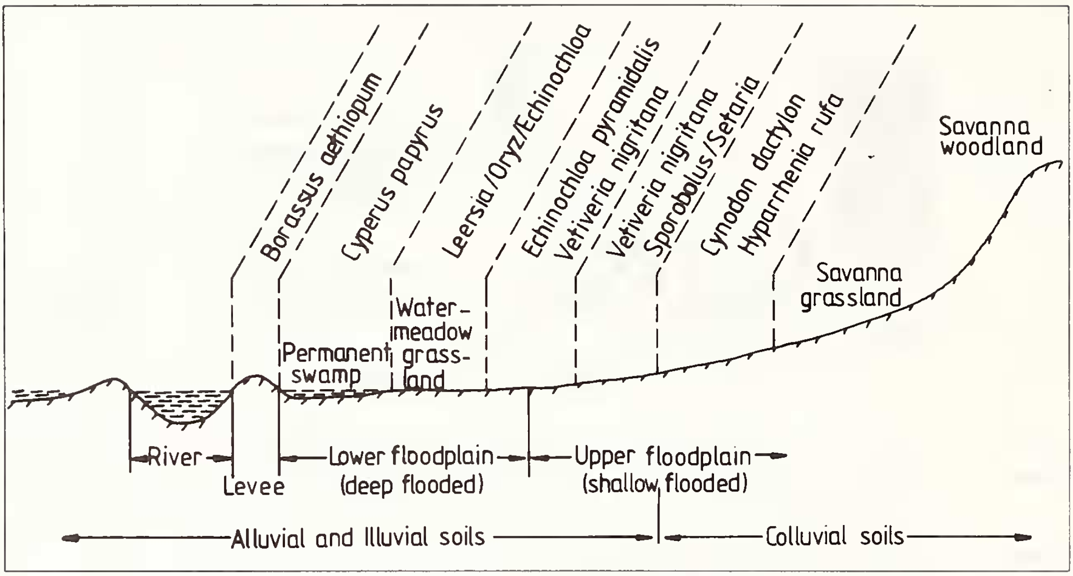

Figure 2. Sectional diagram of the upper Zaire River Basin (Shaba Province, Zaire) showing typical vegetation zonation associated with levées (after Thompson, 1985)

As the level of the floodplain rises through deposition, the river eventually permanently breaches through some overspill notch in a levée, usually upstream. Flow is then diverted in a new direction across the floodplain. This leads to a complex system containing numerous water bodies. Welcomme (1979) distinguished the following:

- Lakes: large features which persist relatively unchanged over a number of years;
- Lagoons: water bodies which remain connected to the river throughout the year;
- Pools: smaller, more ephemeral bodies of water becoming isolated, drying out in some seasons; and
- Swamps: depressions where the soil remains saturated, more or less permanently covered with water

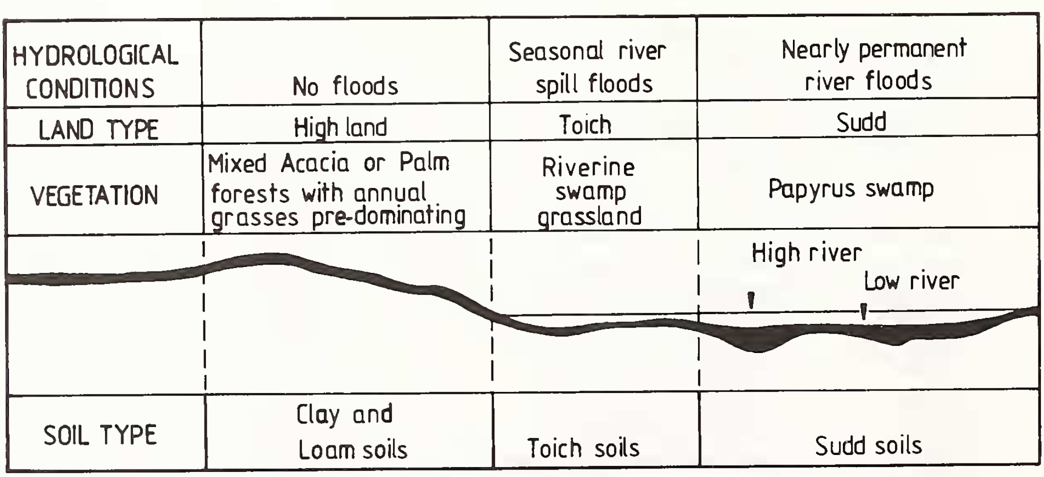

Figure 3. General profile of White Nile floodplain

All these features can be seen in one portion of a floodplain on the Nile in southern Sudan (Fig. 4). Here two lakes, Lakes Nvong and Shambe, are seen along the course of the main river channel, the Bahrel Jebel, a branch of the White Nile. Perennial papyrus swamps line the river banks as well as lagoons and pools which are seen in profusion.

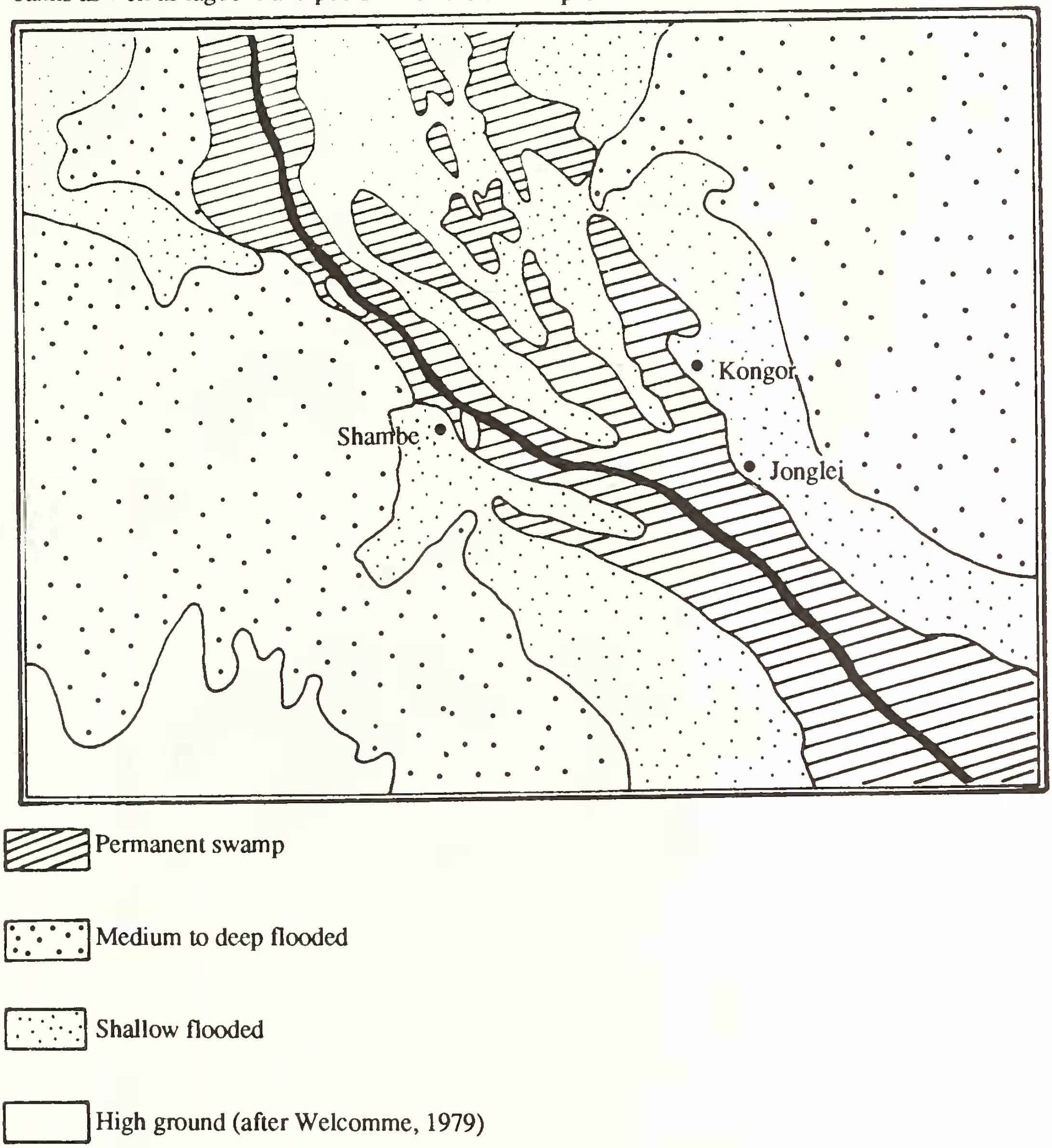

Figure 4. One section of the White Nile Sudd region between Shambe and Kongor (68°N; 30-31°E) Two small lakes (Nuong and Shambe) are shown along with several towns

The pools and lagoons in an African floodplain are dynamic ecosystems in themselves. Their physical features change dramatically with the wet and dry seasons when they often either dry up or fill up. This is clearly seen in a sequence shown for the Senegal River (Fig. 5), based on Reizer's (1974) work, where he shows a flooding sequence which leaves behind only one large lagoon, Vindon Edi Lagoon, which persists for some time.

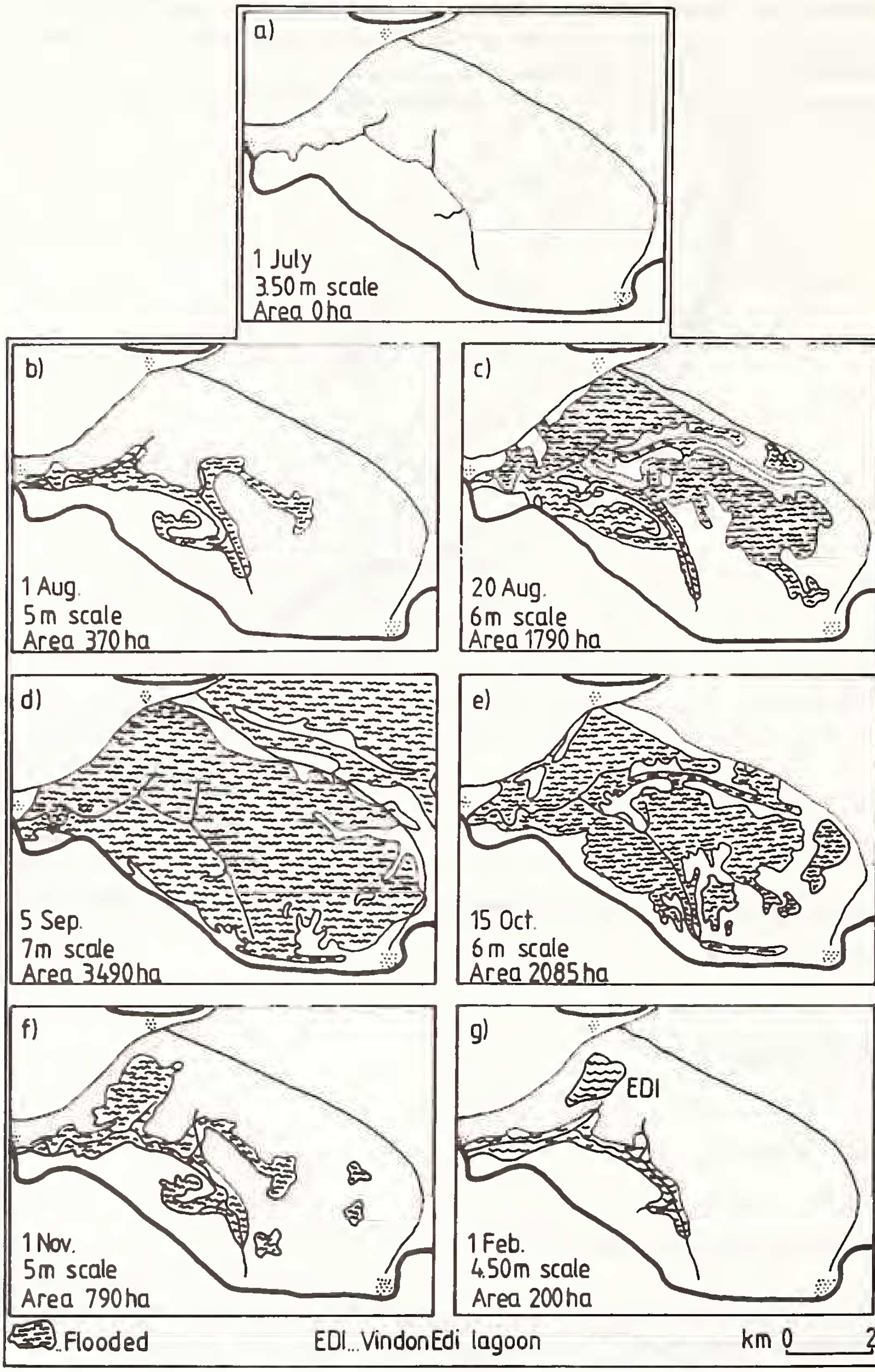

Figure 5. Annual flooding cycle of Senegal River floodplain (after Reizer, 1974)

Major African floodplains

African floodplains of 1,000 kms^{-2} or more are listed in Table 2 and located on Fig. 6. The largest are internal deltas which occur when a river system encounters some geological barrier causing lateral spread over very large alluvial plains. Good examples are: the Sudd region (Fig. 4), Yaerés Floodplain (Figs 7 & 8), Niger Central Delta (Fig. 9), and the Okavango Delta (Fig. 10). The total area of these major flooded wetlands, 290,000 km^2 is reduced during low water periods by approximately 85% to only about 43,500 km^2, but as Thompson (1985) points out, the total areas flooded each year in continental Africa will be difficult to calculate. If the countless smaller regions are included, the estimated total would greatly exceed the below figure.

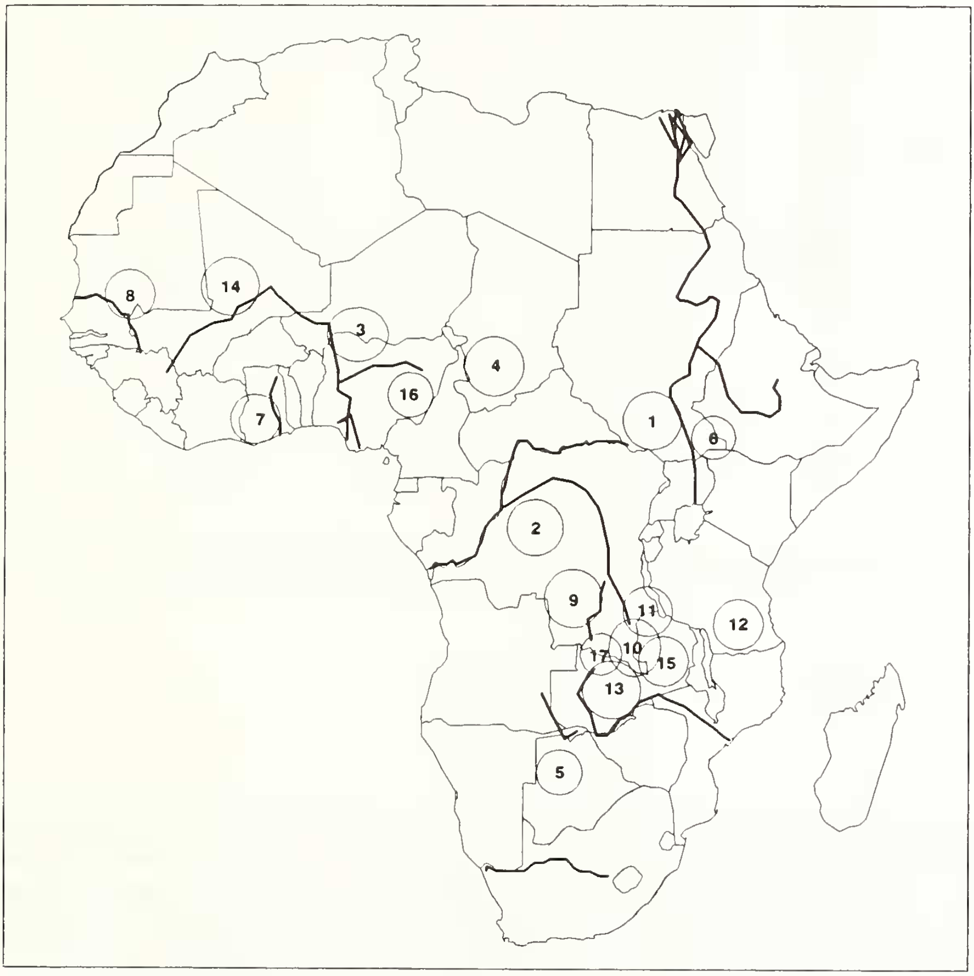

Figure 6. Sketch map of Africa showing the location of major floodplain regions. Main African herbaceous wetlands and waterbodies located as follows:

1. Sudd Swamps of Upper Nile; 2. Middle Congo Swamp Region; 3. Niger Central Basin; 4. Lake Tchad Basin and Yaerés Floodplain; 5. Okavango Delta; 6. Kenamuke Swamp, Sudan; 7. Volta River; 8. Senegal Floodplain; 9. Upemba Basin, Lualaba River; 10. Barotse Plains; 11. Laupula Floodplain, Bangweula Swamp; 12. Rufiji Kilombero Swamp; 13. Kafue Floodplain; 14. Niger River Floodplain; 15. Luiwa Floodplain, Zambia; 16. Benue Floodplain; 17. Lukanga Swamps.

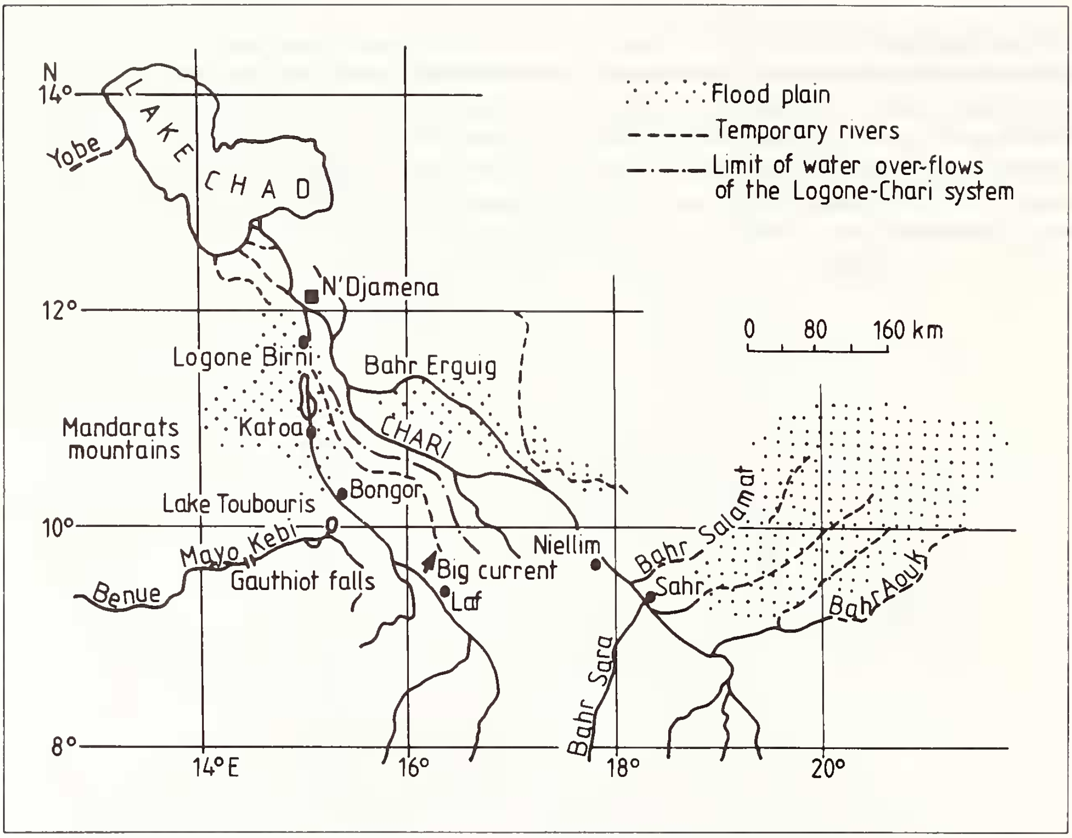

Figure 7. Yaerés floodplain on the Chari and Logone rivers (after Carmouze *et al.*, 1983)

Water and nutrients

Water relations

When dealing with such enormous regions in remote areas where only spot meteorological records are available, only rough estimates can be made of water relations. In large wet regions, the water balance would be complicated by local climatic conditions. Welcomme (1979) noted that precipitation on the floodplain itself saturates the soil, causing local flooding which often precedes the main overspill flood from the river. This is dramatically true in the Sudd region where the rain falls on impervious soil on either side of the river and then drains toward the channel. Extensive flooding may be evident even before the annual river flood occurs.

The inundation of the upper Chari Basin and most other floodplains such as those of the Niger, Lualaba, Zambezi, Volta, Senegal and Kafue, follows similar patterns. However, there are exceptions to the general rule. In the Okavango Delta, peak rainfall coincides with periods of low water and high evaporation in the floodplain; also, local rainfall is so erratic that no regular floodplain saturation may occur before the annual river flood. The water deficit here may be so large that on occasion no water comes out of the system.

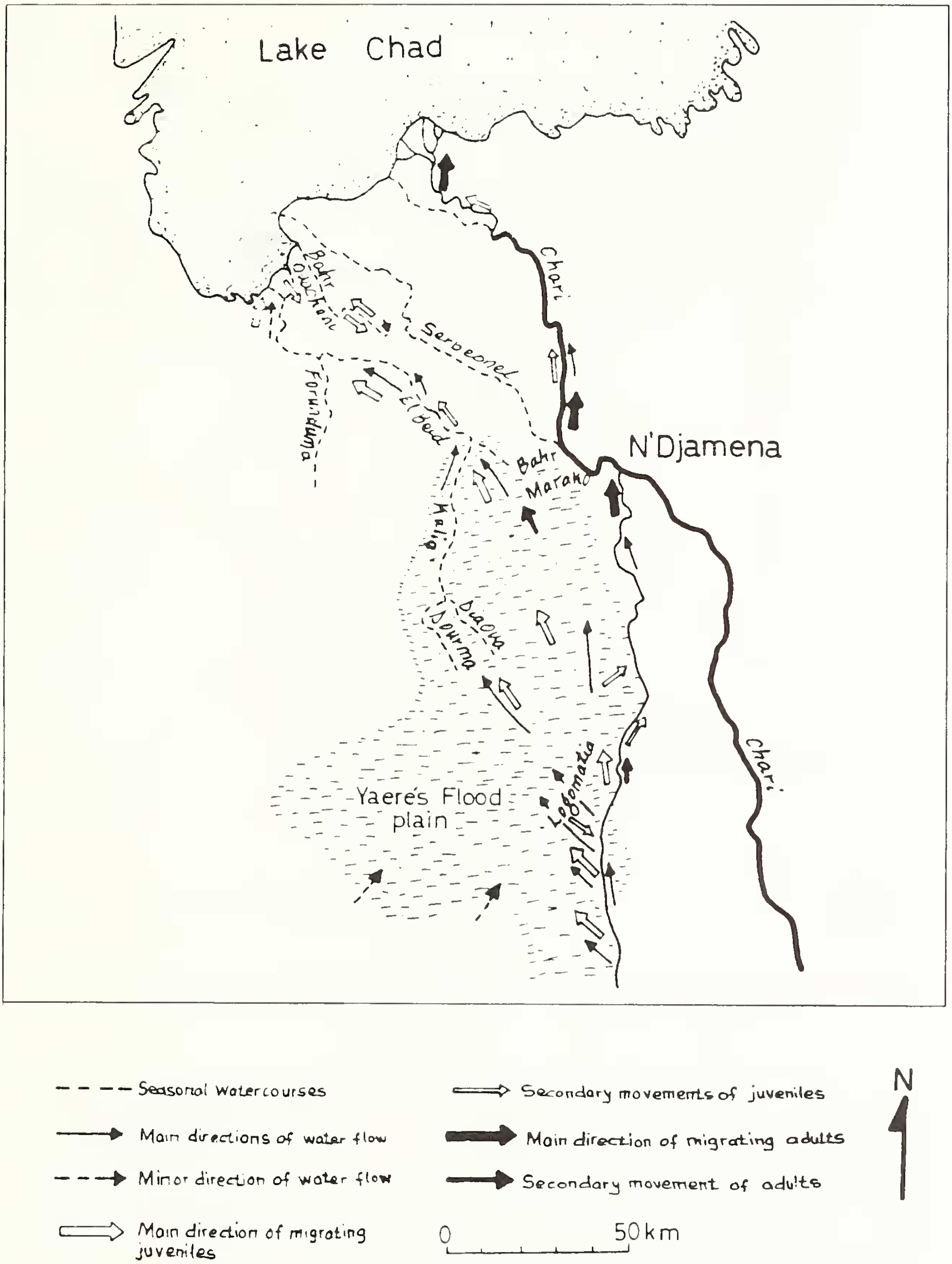

Figure 8. Yaerés floodplain showing annual fish migration routes (after Welcomme, 1979)

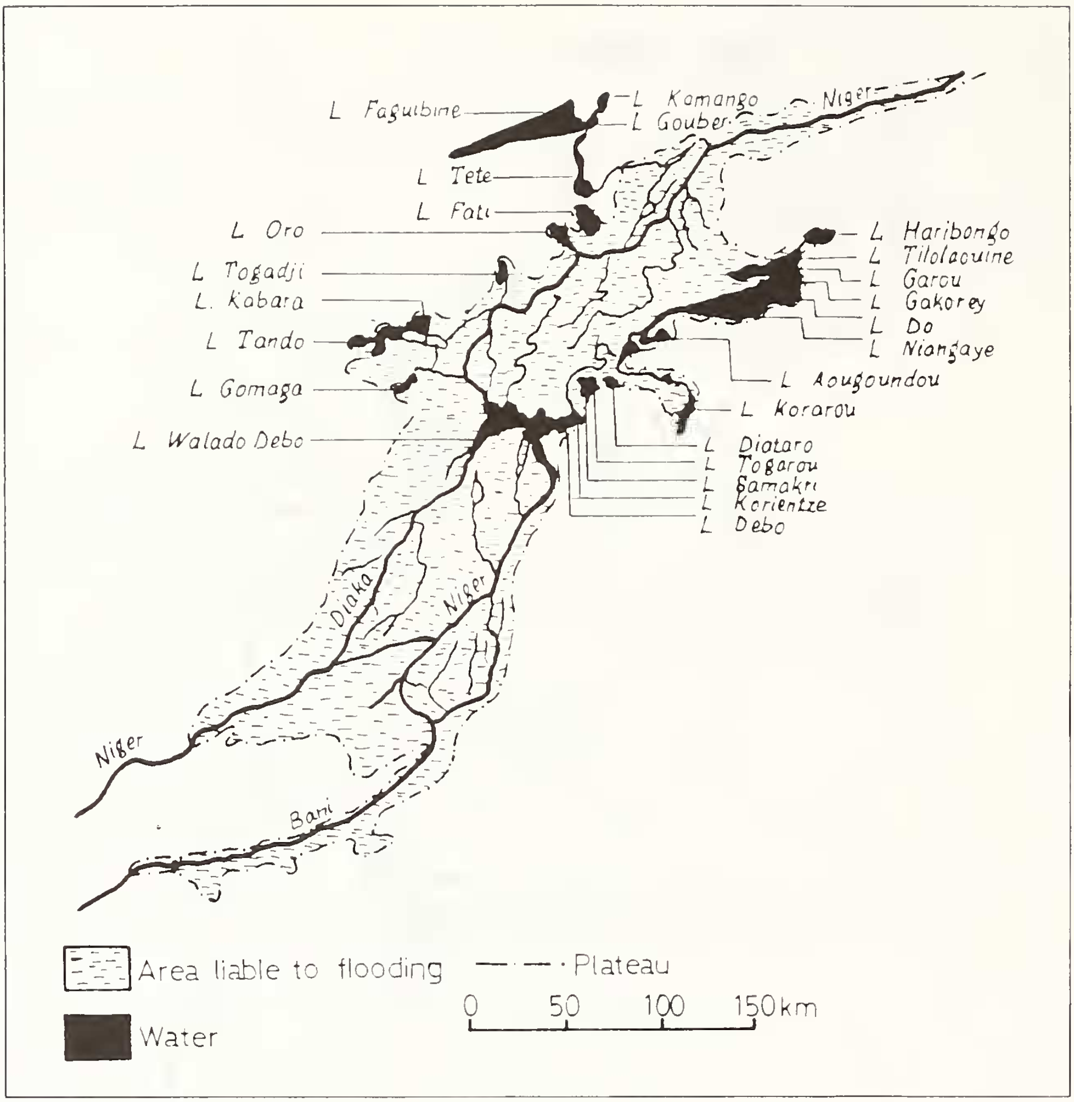

Figure 9. Internal delta of the Niger River showing numerous lakes within the system (after Welcomme, 1979)

Several workers concur that in Africa the evaporation rate in floodplains exceeds precipitation and in general a water loss can be expected during river passage through a floodplain (Table 3). This loss, 46-96% is due to evaporation from open water, evapotranspiration from emergent vegetation, and seepage loss. However, in most areas it is difficult to conceive of seepage loss as being significant because the fine clay deposits typical of floodplain areas would seem to act as a natural barrier to ground water loss. It is true that in some areas, such as the Okavango or Chari regions sand deposits are more prevalent and these would be conducive to ground water loss, and such ground water loss does occur in the Okavango region where the water tables slope away from the main flow channels. Water and mineral balance studies in the Lake Chad region also point to about 8% seepage loss in the sandy substrata in the southern part of the lake (Carmouze *et al.*. 1983). In many areas, including Lake Chad, the underlying substrate is a mud or compacted clay, or the surrounding soil may be so impervious, as in southern Sudan that water remains on the ground after rain, slowly moving downslope, a phenomenon referred to as "creeping flow" by local hydrologists.

Evaporation and evapotranspiration (ET) in floodplains are even more controversial topics than seepage. Evaporation would occur from a variety of surfaces such as: open water, dry soil or wet mud and would be complicated by advected energy, which is high in open areas low inside the vegetation. Albedo also will vary with degree of wetness, burning of vegetation and other factors. The ET of papyrus has been shown to be less than that of open water (Rijks, 1969), possibly because it forms a closed canopy. On the other hand, open stands of an emergent macrophyte, e.g. *Phragmites sp.* will lose water at rates considerable in excess of those expected from open water (Imhof & Burian, 1972).

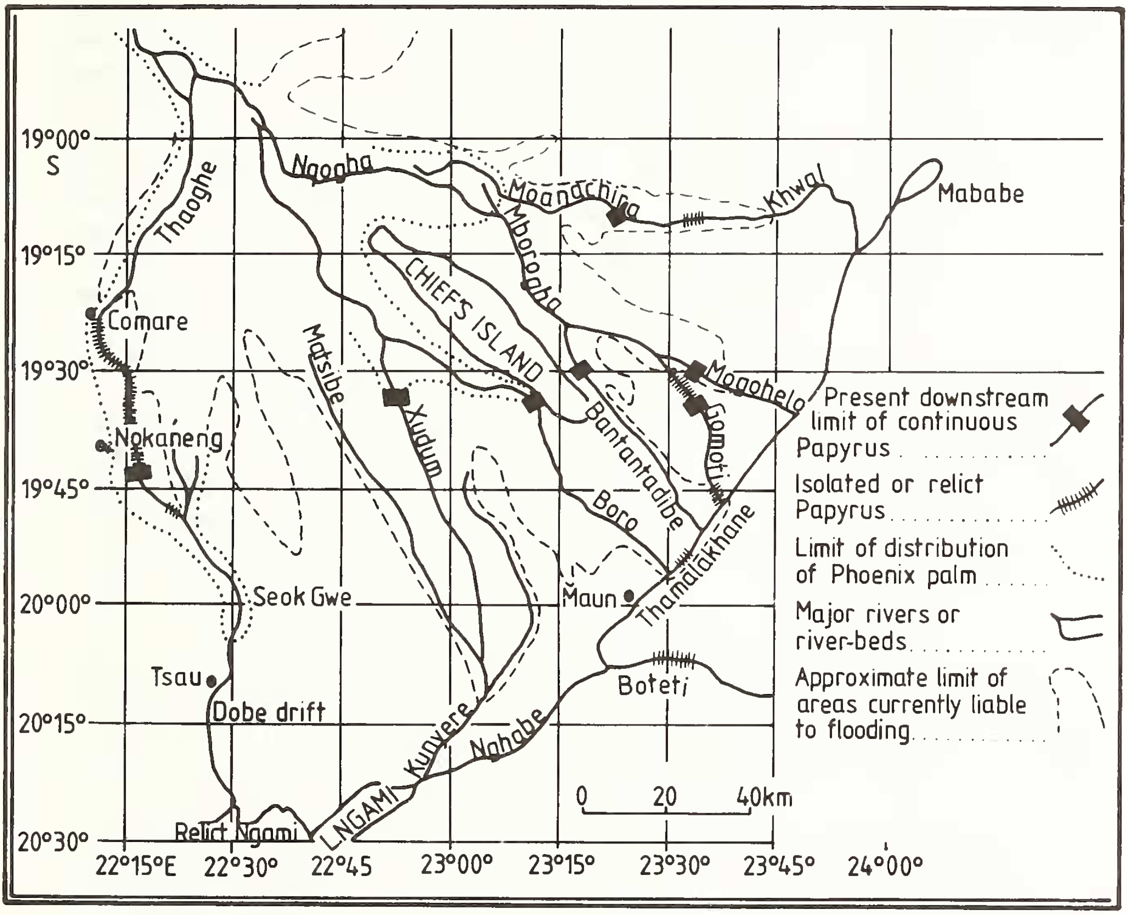

Figure 10. Distribution of papyrus and phoenix palm associations in the Okavango Delta (after Smith, 1976)

Table 3: Annual water balance in several floodplains (data from Welcomme, 1979 and Thompson, 1976)

Floodplain	Station	Precipitation (mm)	Evaporation (mm)	Input (mm)	Output ($x10^{10}m^3$)	Net Loss %
Niger	Bamako, Mali	1120	2150	7.11	3.82	46
Nile (Sudd)	Wau, Sudan	1100	1900	2.70	1.40	48
Okavango	Maun, Botswana	434	1800	1.18	0.06	95

Water chemistry and nutrient dynamics

Generalizations about water chemistry in floodplains are difficult to make because of inter- and intrahabitat complexity. The most often measured floodplain parameter is conductivity (see Table 2), but measurements are usually taken in open standing water and may not be a useful indicator of floodplain conditions. Conductivity in the main channel seems mostly influenced by: dilution with flood or rain water; solution input from land; swamps or floodplain drainage; evaporation; uptake by the biota; and absorption by sediments. Welcomme (1979) pointed out that all of these effects tend to produce higher conductivities in the dry season both in lagoons and river channels resulting in an inverse relationship between water depth and conductivity in African rivers. A secondary conductivity maximum due to solution input occurs when the river water invades the floodplain. The conductivity rise is usually accompanied by a pH drop due to acid swamp water input. The Niger central delta is an exception with a pH rise which remains unexplained. The conductivity rise and pH decrease is also accompanied by a decrease in dissolved oxygen which is typical during stagnant swamp or floodplain conditions. During dry seasons standing water in floodplains becomes stagnant, and this stagnation is strongly stratified due to a lack of strong wind effects and intense insolation. Sudden reductions in air temperature association with a cold front or a strong wind storm can break down this stratification. This results in an upwelling or "overturn" which can raise the oxygen deficit and cause chemically reduced bottom waters, and fish kills often result (Welcomme, 1979). Overturns and fish kills can also be caused during the entry of river floodwater at the beginning of the flood season. This is an indication of how strongly reduced the bottom water can be in floodplains.

One way of looking at changes in water chemistry in a floodplain is to compare the input to the output and assume all net changes can be ascribed to the overall system, that is, by using a "black box" approach. In floodplains or other large wetlands this approach is taken more out of futility than anything else. For example, longitudinal transects of water chemistry were done by Talling (1957) and Bishai (1962) along a 1,000 km stretch of the Nile river where it passes through the Sudd region along the Bahr el Jabel. In this section of the river the results of both Talling and Bishai show that conductivity, alkalinity, çalcium and chloride levels were erratic and did not follow any distinct pattern. This agrees with a study by Gaudet (1978) who found that tropical swamps had little effect on the salinity of the through-flow, as long as the water passed freely through the system. Both Talling and Bishai did find some effects on water chemistry along the 1,000km stretch of the Nile in that there were decreases in oxygen, sulphate and pH, and a rise in carbon dioxide, silicate, ammonia and iron in the river. Many of these changes could be explained on the basis of decomposition effects, the sort of general effects that are typical of mires and floodplains (Howard-Williams & Gaudet, 1985).

A recent study was carried out in the Sudd Region to determine the ecological impacts of the Jonglei Canal (Anon, 1983). Part of the study was devoted to determining the effects of the Sudd on the chemistry of the water passing through. Because of the complexity of the system, earlier results as above and the enormous overriding effect of evaporation (a 50% loss of water occurs while it transits the Sudd) it was assumed that the effects of the whole system would be of limited magnitude. The study therefore concentrated on only a small portion of the whole Sudd. Two permanent sampling stations were set up, one at Bor, where the White Nile can be sampled prior to entering the Sudd and one downstream at Dhiam-Dhiam where a branch of the main White Nile river (the Atem) has passed through 75 km of floodplain and swamps. The effects noted (Table 4) were not much different from those noted in previous studies. The authors used the general model proposed by Gaudet (1979) for East African wetlands which proposes that three phases could be detected in the papyrus swamps on the northern edge of Lake Naivasha in Kenya, that is: stagnation, through-flow and drying. Apparently the Sudd region below Bor follows a remarkably similar pattern to the Lake Naivasha system. This even includes a rough correspondence of annual cycles. The results of the Sudd study show an overall decline in oxygen and pH, with increases in dissolved carbon dioxide. A decrease also occurred in nitrate, phosphate and sulphate as expected. It is significant that high levels of dissolved silicon were found entering and leaving the system. All of these results are similar to those found by Gaudet working on papyrus swamps in Uganda and Kenya (Howard-Williams & Gaudet, 1985).

Table 4: Summary of the processes at work in the Sudd wetlands, and the overall effects on water passing through the system (based on Anon, 1983)

Phase	I	II	III
Status	Stagnation	Through-flow	Drying
Season	Late dry	Wet	Late wet-Early dry
Water balance	Low river input, Minimal outflow	Early pulses of river water inflow	Minimal inflowwith continued drainage
Processes in operation	Decomposition and evapotranspiration	Flushing due to influx of river water	Stagnation begins
Water chemistry increase, rise in phosphate and iron	Turbidity decrease, colour	Alkalinity increase	Rise in conductance
Effect on receiving waters	Very little outflow	Early flush of high alkalinity, later flush is more dilute	General outflow of high conductance water

The Sudd study concluded “the Sudd is unlikely to act as a long-term nutrient trap,” because most of the nutrient inputs into the Sudd will be taken up into the organic plant fraction and this will be recycled within the wetlands or flushed out into the river. However, the Sudd wetlands do have an ability to take up large amounts of nutrients on a short-term basis and this phenomenon is important in that the wetlands involved can act as a buffer to prevent large flushes of nutrients from entering receiving waters.

The amounts that can be taken up can be estimated if we assume that much of the swamp and floodplain production is turned into detritus. This process would remove large amounts of soluble nutrients from the water passing through the system, and this in turn would affect the chemistry of water downstream. A rough estimate based on this assumption (Table 5) shows that the Sudd could have less effect on major inorganic ions such as Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg) and Chloride (Cl), than on nutrient ions which are present at much lower concentration levels, such as Nitrogen (N), Phosphorous (P), Sulphur (S) and Iron (Fe). the nutrient ions would be even more strongly affected than this estimate because they would be in great demand by the river biota. In theory, the swamps and floodplain would completely remove nutrient ions from the river and flood water. In practice, however, the vegetation in these habitats probably takes up much of its Phosphorous (P), Sulphur (S) and Iron (Fe) from local floodplain soils and the large nitrogen demand is probably met by Nitrogen-fixation, a process that has been suggested by other authors to be a common feature of wetlands (Bristow, 1974). All of the nutrients so trapped in organic matter will be released later if and when the organic matter is degraded downstream.

Table 5: Potential effect of one part of the Sudd on the chemistry of Nile river water

Element	Rate of removal by detritus[1] (g/m^2)	Vegetation[2] (tonnes x 10^3)	Removal by from river[3] (tonnes x 10^3)
N	67.83	678	3
P	2.61	26	1
S	31.71	317	46
Fe	7.39	74	12
Na	7.48	75	230
K	5.823	58	81
Ca	1.13	11	173
Mg	3.65	37	55
Cl	0.70	7	152

[1] Based on Gaudet (1978, 1979)
[2] Assuming an immediate low water area of 10,000 km^2
[3] Concentration of Nile above Sudd region, based on Talling (1957), Bishai (1962), and Kilham (1972). Also assumes a discharge of 23 x 10^9 m^3 (Rzoska, 1976)

Table 6: Effect of drought conditions on water chemistry and phytoplankton in a seasonally inundated part of the Okavango Delta (data from Reavell, 1979) based on 13-37 samples

Date	Total discharge from delta (m^3s^{-1})	Total P (gl^{-1}) (a)	Total N (gl^{-1}) (b)	Temp (°C)	Surface O_2 (mgl^{-1})	Phytoplankton (cells l^{-1})
iii/1972	—	—	—	28.2	—	—
vi/1972	—	60	425	17.7	6.9	—
viii-ix/1972	9.32	95	604	21.4	6.3	—
ii-iii/1973	0	171	994	29.2	4.5	54,038
v/1973	0	252	2,772	24.2	7.5	683,961
ix-x/1973	3.48	86	652	25.2	—	41,103
xii/1973	0.33	86	277	26.4	7.0	17,889
ii-iii/1974	4.04	119	176	26.4	7.6	8,545
vi-viii/1974	11.16	60	214	19.6	6.4	7,121

(a) Sol. react. P plus org. P
(b) Total dissolved inorganic only

Internal recycling may also be possible because of the large amounts of nutrient material trapped within floodplains. In many floodplains evaporation leads to an increase in concentration of salts. This is obvious during droughts, such as the dramatic drought in the Okavango delta in 1973. At this time evaporative loss was not balanced by local rain input, and Reavell (1979) noted that as the floodplain and swamp water contracted in to discontinuous pools there was an increase in total dissolved solids from 83 to 223 mg^{-1}. Such water, when trapped during dry weather inside the floodplains, becomes a concentrated source of nutrients. This, along with the creation of still-water conditions, leads to an excellent growth environment for hypereutrophic algal species. Reavell (1979) documented this cycle in the Okavango delta (Table 6), and similar events are also known elsewhere in Africa. In the Chad basin when the Chari and Logone rivers overflow their banks and rapidly flood the Yaerés floodplain, the same nutrient flush is seen (Beadle, 1974). At that time, the dried organic and mineral matter, along with ashes from bush fires and droppings from animal herds which previously inhabited the dry river beds, begins to decompose and to dissolve. Within a few days an explosive growth of phytoplankton occurs, followed by a zooplankton bloom and later by growth of macrophytes. In this floodplain, grasses and emergents (Polygonaceae and Alismataceae) occur in shallow water, while the genera *Pistia*, *Nymphaea*, *Stratiotes* and *Utricularia* occur in the deeper portions. The floods later subside and leave great numbers of fish stranded within the vegetation-choked water. Later still the area begins to dry down again and is then accessible for dry season animal grazing until the next flood, when this “instant eutrophication”, or nutrient build up, will again occur (Beadle, 1974).

Productivity

Production and biomass

Floodplains are dominated by herbaceous monocotyledons, the most predominant genera being the tropical wetland grasses, *Sporobolus, Echinochloa, Oryza, Vossia, Phragmites, Paspalum, Miscanthidium*, and *Panicum*. Sedges, especially *Cyperus papyrus* and Bulrush (*Typha* sp.) are also common in the deeper floodplain water.

Among these genera, the most well-studied are papyrus and bulrush. Net production rates determined for these two examples are very high. Papyrus net production on a sustained basis is 48-143 tonnes (dw) $ha^{-1}y^{-1}$ (Thompson *et al.*, 1979). For comparison, it should be noted that maize or sugar cane production can also be sustained at this rate, but only under heavy applications of artificial fertilizer. Papyrus maintains its high rate of production under natural, low nutrient conditions. *Typha domingensis* in the Lake Chilwa swamps averages 16 tonnes $ha^{-1}y^{-1}$ (Howard-Williams & Lenton, 1975). Net production rates for *Phragmites australis* have been predicted at 58 tonnes $ha^{-1}y^{-1}$ if growing under tropical conditions (Thompson *et al.*, 1979). Tropical wetland grasses (*Paspalum repens*) are known to attain 12-16 tonnes $ha^{-1}y^{-1}$ (Junk, 1970), while the estimated net production of seasonally-flooded grasslands would be about 10-20 tonnes $ha^{-1}y^{-1}$ (Thompson, 1976).

In addition to the dominant emergents, there is commonly a mixture of submerged and floating macrophytes at the river channel edge and in open areas of standing water. Indeed, pools and lagoons along the Nile and Zaire Rivers, and their attendant floodplains may be completely covered with *Pistia stratiotes* and/or *Eichornia crassipes* during stagnant water conditions in the dry season. *E. crassipes* alone is capable of 11-33 tonnes $ha^{-1}y^{-1}$ (Westlake, 1975). Overall, most African floodplains should be capable of a sustained net production approaching 20 tonnes $ha^{-1}y^{-1}$. On a continent-wide basis this would roughly amount to an annual net production of 0.8×10^9 tonnes using the area estimated at low water. For comparison, the total annual net production of tropical grasslands on a worldwide basis would be between 4 and 30×10^9 tonnes (Lieth, 1972)

The high rate of production in floodplains is certainly a factor in the overall productivity of these areas, especially in Africa where they support large numbers of domestic and wild animals, e.g. lechwe (*Kobus*) in the Kafue River floodplains (Werger & Ellenbroek, 1980). Another factor here is the quality of floodplain grasses. Van Rensberg (1971) found the Kafue flats floodplain grasses were "grasses of high fodder quality, containing a relatively high content of crude protein. They are also highly palatable, even when dry." In contrast, grass species from non-flooded areas lose their palatability on drying. Thus even in regions of similar grass production, the floodplain species will always be more attractive to herbivores.

Vegetation

Floodplain species

The general vegetation of floodplains includes a large range of life forms. Within standing water bodies, pools and rivers inside the floodplain we can find typical hydrophyte associations (obligate water-plants). At the other extreme are the terrestrial plants that can tolerate a degree of flooding. The majority of the species that occur are emergent amphibious plants. Their habit ranges from herbaceous to woody, but they more often than not are emergent rhizomatous monocotyledons, predominantly grasses and sedges.They fali within the main classes of species for African wetlands established by Thompson (1985). Among the major wetland types listed, (Table 7) we are dealing here with the seasonal types (section II(a) (2)

A good starting point for the study of a typical floodplain flora is the partial list from Lebrun's work in 1947 (Table 8). We see in this list a predominance of rhizomatous emergents (15 out of the 18 species). Many of the species mentioned are also common to perennial swamps. Thus, bulrush (*Typha* sp.) and papyrus (*C. papyrus*) exist within the floodplains of large internal deltas. In addition to these typical species, it would also be appropriate to list several floating Sudd species which are common to floating meadows, or floating islands. such as *Vossia cuspidata*, *Saccolepis interrupta*, *Echinochloa scabra* (= *E. stagnina*), *Oryza longistaminata* and *Jardinea congoensis*. These can often be seen inside floodplains during high water.

Major floodplain associations

The easiest way of describing floodplain associations has been the use of profiles drawn to scale, transecting the major channels or rivers concerned. The larger floodplains, however, defy description using such methods. They often are simply traced from satellite imagery. The result is that we are left today with very general descriptions of African floodplains which often cover large geographic areas. A case in point are the diagrams shown in Vesey-Fitzgerald (1973) (Fig. 11). He outlined several floodplains common to the valley grasslands along the Kafue River. In the upper part of the river, valley grasslands drain freely to allow a gradual drying and a distinct association develops (Fig. 11 a). However, there are many areas especially in the Kafue flats where drainage is impeded because of silt deposition (Fig. 11 b). Here, in addition to the valley grasslands the fioodplain supports associations dominated by *E. pyramidalis*, *E. haploclada*, and *V. cuspidata* and closer to the mainstream along the levées one finds *E. scabra*.

Table 7: Main classes of plant species, and communities in African wetlands (Thompson 1985)

I. MAJOR CLASSES OF SPECIES
- A. Monocotyledons
  - 1. Graminae
    - a. Large wetland grasses
    - b. Small wetland grasses
  - 2. Other herbaceous genera
  - 3. Woody genera
- B. Dicotyledons
  - 1. Herbaceous
  - 2. Woody
- C. Gymnosperms
- D. Pteridophytes
- E. Bryophytes

II. MAJOR WETLAND TYPES
- A. Freshwater herbaceous wetlands
  - 1. Permanent
    - a. Reed swamps
    - b. Bog fen and moorland
  - 2. Seasonal
    - a. Black clays, pans and dambos
    - b. Floodplains and valley grasslands
    - c. Alkaline grasslands
- B. Freshwater swamp forests
  - 1. Permanent
  - 2. Seasonal
    - a. Floodplain forests
    - b. Riverine and gallery forests

III. MAJOR WETLAND PLANT COMMUNITIES
- A. Sudd communities
- B. Reed communities
  - 1. *Vossia* swamps
  - 2. *Cyperus* swamps
  - 3. *Miscanthidium* swamps
  - 4. *Cladium*, *Phragmites* and *Typha* reed swamps
- C. Edaphic grasslands
  - 1. Hydroseres
  - 2. Secondary grasslands
  - 3. Black clay, pan and dambo communities
  - 4. Alkaline grasslands and swamps
- D. Edaphic forests
  - 1. Permanent swamp forest
  - 2. Seasonal swamp forest
  - 3. Riverine and gallery forests secondary forests
- E. Montane wetlands

Table 8: Species common to flooded regions in Central Africa (after Lebrun 1947)

SEDGES:
Cyperus papyrus L.
C. haspan L.
C. articulatus L.
C. dives Del
Pycreus mundtii Nees.

GRASSES:
Leersia hexandra Swartz
Phragmites mauritianus Kunth.
Echinochloa pyramidalis (Lam.) Hitch. & Chase
E. scabra (Retz) Beauv. (= *E. stagnina*)
Vossia cuspidata (Roxb.) Griff.
Oryza longistaminata A. Chev. & Roehr
Paspalidium geminatum (Forssk.) Stapf
Sporobolus robustus Kunth.

BULRUSH:
Typha australis Schum. & Thonn.

HERBS & SHRUBS:
Aeschynomene elaphroxylon (Guill. & Perrot) Taub
Mimosa asperata L.
Pluchea ovalis (Pers.) DC.

The typical occurrence of *V. cuspidata* and *E. scabra* close to the mainstream or in deep-flooding habitats will be discussed below in relation to the Sudd region. But first, it would be of interest to consider the most common successional types, hydroseres, within the floodplains. Thompson (1985) has pointed out that in the savanna regions of Africa, the most common hydrosere is *Vossia-Oryza-Hyparrhenia.* He noted that this sequence from an aquatic emergent grass to a typical savanna terrestrial type occurs in the Sudan, the Kafue Flats, the Bangweulu floodplain and generally throughout the West African river systems. The relative proportion of each component within the hydrosere varies from site to site, e.g., *Vossia* predominates in the fringing wetlands of the Zaire river, *Oryza* sp. dominates in the Kafue Flats, *E. scabra* is most important in the inland delta of the Niger River (Mali), and *E. pyramidalis* dominates in many of the Central African valley floodplains.

Thompson (1985) also made the point that there is much variation within each locality. Many other grass species are usually found at any one site. A good example is shown in Fig. 12, where two Zambian floodplains are compared. We see here that in addition to the inevitable *Vossia* and *E. scabra*, there is a whole range of grass species within each floodplain. Unfortunately, in such a diagram there is a tendency to compress the species so that the mosaic pattern is not evident. In reality the mosaic or patchwork pattern is obvious and quite important. In the mosaic we can often see large differences in the distribution of non-dominant, minor species. Thompson pointed out that certain non-dominant floodplain grasses show great diversity, inhabiting a number of important niches. For example, *Cynodon dactylon* can exist as an understory grass within a community dominated by *E. pyramidalis*, either as an associate of water-meadow grasses, as a sward-former in its own right, or as a member of the marginal community in a floodplain grass mosaic.

Differences in species composition or dominance will also be related to local differences in soil type and flooding conditions. Regarding soil types, Reizer (1974) showed a clear difference in floodplain species along the Senegal River where there were large differences in soil types (Fig. 1, 3A, B, and C).

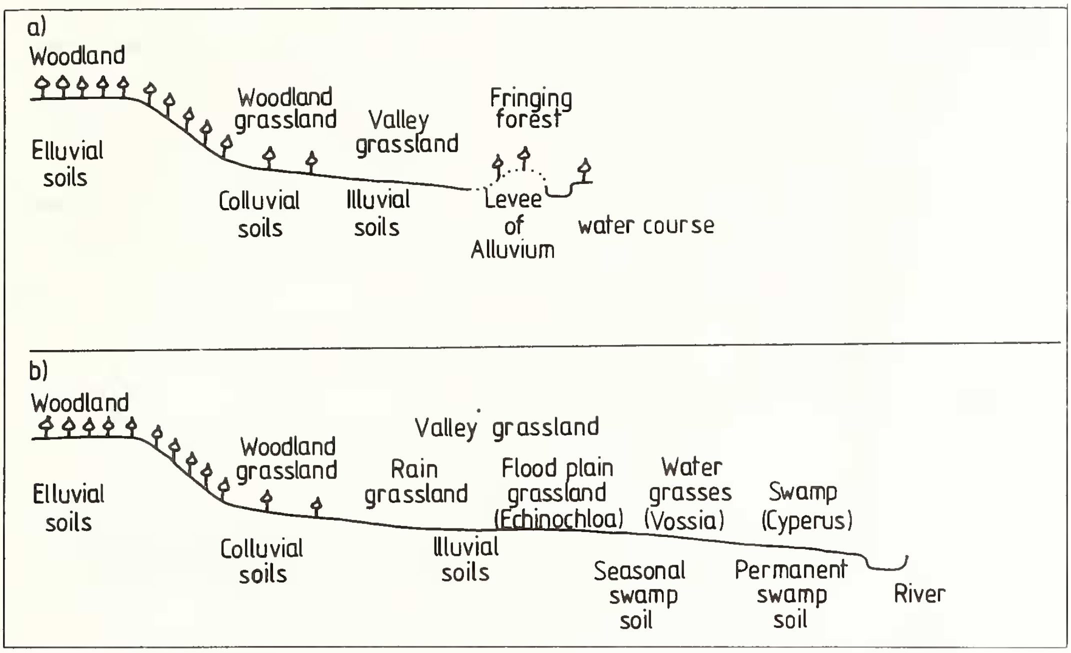

Figure 11. A. Diagram of a section downslope into a valley with free drainage and distinct levées on either side of the main channel

B. Diagram of the gradual change along a slope with impeded drainage. Both sections in central East Africa (after Vesey-Fitzgerald, 1973)

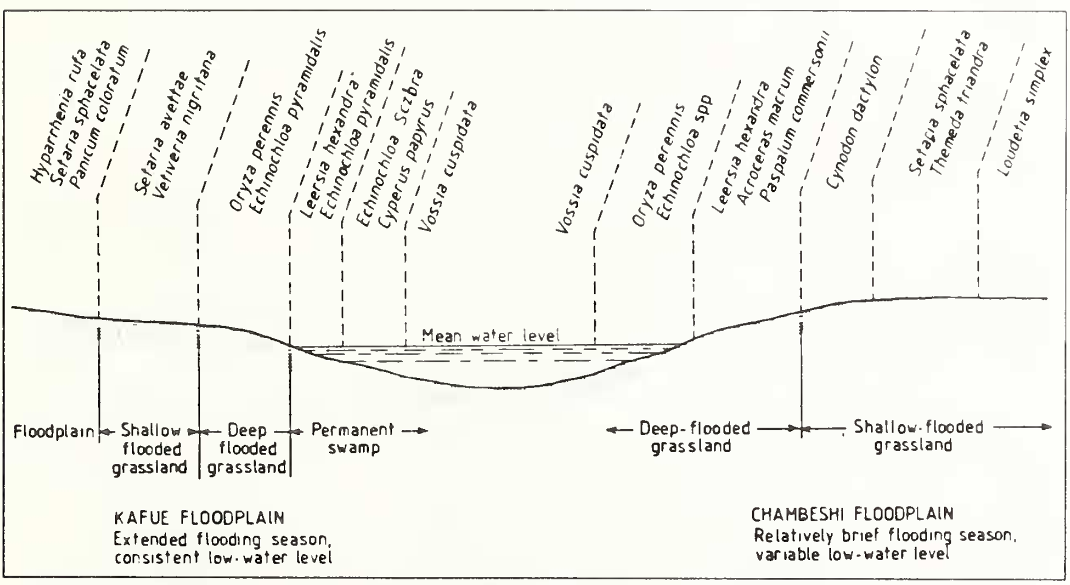

Figure 12. Composite of two Zambian floodplains. Each site had different flooding regimes and different soil types but extensive grass associations occur in both cases (after Thompson, 1985, from Astle, 1965 and Van Rensberg, 1968)

Species distribution

Certain large obvious species within floodplains have been studied because of their value as indicator plants. Smith (1976) in a study of the Okavango Delta used both papyrus and a phoenix palm as indicators. Because of the difference in rates of colonization between the two species their limits of distribution (see Fig. 10) at different periods of time indicated changes in permanent high water tables.

Other indicator plants in floodplains which are often cited, are the salt-tolerant species that favour alkaline saline floodplains. In West African profiles, for example. Reizer (1974) described a *Phragmites-Sporobolus-Tamarix* association which was clearly indicative of saline conditions. In fact, *Sporobolus* is often cited as the most adaptable genus in African alkaline saline floodplains (Thompson 1985). In Central and East African floodplains another useful indicator of saline habitats is *Cyperus laevigatus*. This is clearly seen in the profile taken by Lebrun (1947) across a small river emerging from a saline spring (Fig. 13).

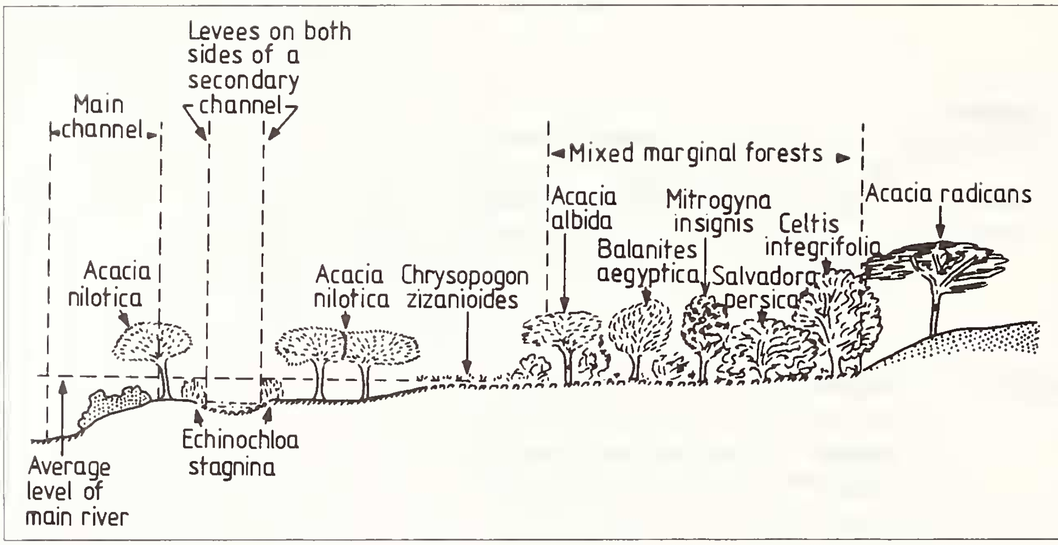

Fig. 13. Transect through the Senegal River floodplain (after Reizer 1974), where *E. scabra* can be found along levées in secondary channels in association with a small tree, *Acacia nilotica*.

A comparison of lists of species from different African floodplains can be seen in Thompson (1985). His consideration of several lists from diverse regions within Africa shows a certain common trend in the continental floodplain flora. This is expected because of the wide distribution of many freshwater macrophytes. Species lists and/or general descriptions of floodplain vegetation can be found in the references cited in Table 9. Here some distinction is made between major floodplains associated with large rivers and those present on smaller rivers and lakes.

The distribution of some tree species in floodplains is correlated with animal activity. Feely (1965) found that the hippopotamus (*Hippopotamus amphibius L.*) influences the establishment of *Acacia albida* (Del.) along the Luanga and Zambezi river valleys in Zambia. These animals along with other wildlife eagerly seek out the foliage and ripe pods of *A. albida*. The seed is dispersed and germination enhanced by passage through their digestive system. As a result of hippopotamus travel inside floodplains, the young trees are regularly associated with newly deposited silt along the river meanders. Feely considers this species a pioneer on the levées. Its roots tolerate submergence for several weeks or a few months, but the foliage must stay above the flood water for the young trees to survive. This is possible because of its fast growth rate during initial colonization (1.05 my^{-1}).

Some work has been done on differentiation of species within the complex mosaic typical of floodplains. The work of Sutcliffe (1976) stands as a landmark in this respect. Within the Sudd region on the White Nile in the region south of Bor (Fig. 14) he differentiated the following communities:

a) grassland dominated by *Phragmites mauritianus*, containing *Echinochloa pyramidalis* and *Oryza longistaminata*;
b) grassland composed of varying portions of *E. pyramidalis* and *E. scabra*
c) semi-permanent swamp with *E. scabra* and *Vossia cuspidata*
d) permanent papyrus swamp, and
e) open water.

Each of these communities graded into one another along the river, but a fairly pronounced boundary was evident between "shallow-flooded" species (*P. mauritianus, E. pyramidalis* and *O. longistaminata*) and "deep-flooded" species (*C. papyrus, V. cuspidata*, and *E. scabra*). Off the main rivers in basins, the upstream region supported the shallow-flooded species, while the downstream end of the basin contained the deep-flooded species. Sutcliffe (1976) also calculated the percent plant cover along 16 transects (Fig. 14) at different vertical heights, the level of the substrate above mean datum. He found a correlation between height and percent cover for shallow-flooded species. Here *Phragmites* occupied the highest level while *E. pyramidalis* and *Oryza* sp. were present at lower levels. Deep-flooded species, on the other hand. showed no evident correlation between level and cover. But in the deep-flooded communities the species composition depended on position rather than level, e.g. at the lower, wetter levels *E. scabra* was widespread in the floodplains, while *Vossia* sp. and *Papyrus* preferred sites near the rivers, with papyrus near the lower end of each basin.

Table 9: References on floodplain vegetation associated with African water bodies (see also the annotated bibliography in Thompson. *et al.*, 1985)

		Country	Author
I.	MAJOR FLOODPLAINS ON MAJOR RIVERS		
	White Nile	Sudan	El Hadidi (1976), Anon (1983)
	Niger	Nigeria	Cook (1968)
	Okavango	Botswana	Smith (1976)
	Zaire	Zaire & C. Afr Republic	Schmitz (1971), Germain (1952)
	Zambezi	Zimbabwe	Muller & Pope (1982)
	Volta	Ghana	Lawson (1963)
	Senegal	Senegal	Reizer (1974)
	Kafue	Zambia	Douthwaite & Van Lavieren (1977), Van Rensberg (1971)
II.	OTHER FLOODPLAINS		
	A. **Smaller rivers**		
	Ruzizi	Zaire	Germain (1952)
	Pongola. Tugela, Berg & Tuskei	South Africa	Musil *et al.* (1983), Harrison (1964), Oliff (1959), Allanson (1961)
	B. **Man-made lakes**		
	Lake Kainji	Nigeria	Chachu (1979)
	Lake Volta	Ghana	Hall *et al.* (1971)
	Lake Kariba	Zimbabwe, Zambia	Bowmaker (1973), Magadza (1970)
	Lake Nasser-Nubia	Egypt, Sudan	El Hadidi (1976)
	Lake Cabora Bassa	Mozambique	Jackson & Davies (1976)
	Lake Nyumba-ya-Mungu	Tanzania	Welsh & Denny (1978)
	C. **Natural lakes**		
	Lake Naivasha	Kenya	Gaudet (1977)
	Lake Sibaya	South Africa	Howard-Williams (1980)
	Lake Chad	Chad	Leonard (1969), Iltis & Lemoalle (1979)
	Lake Kivu	Rwanda, Zaire	Van der Ben (1959)
	Lakes Mobutu & Edward	Uganda, Zaire	Van der Ben (1959)
	Lake Chilwa	Malawi	Howard-Williams & Walker (1974)
	Lake George	Uganda	Lock (1973)
	Lake Bangweulu	Zambia	Verboom (1975)
	Lake Victoria	Uganda, Kenya, Tanzania	Lind & Morrison (1974)

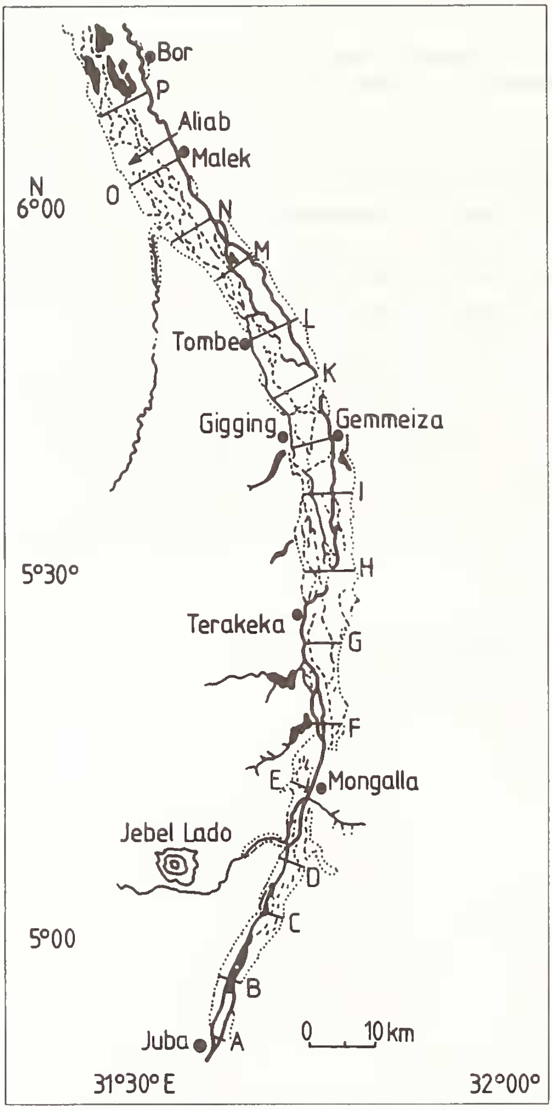

Figure 14. Floodplain on the White Nile from Bor to Juba showing 16 transects, A-P. This region is south of that shown in Figure 4.

Sutcliffe (1957) also examined the distinct boundary which exists between the shallow- and deep-flooded communities. He found that the distance of the boundary from the river edges varied considerably but followed the water-slope very closely. The water-slope depended on: (a) the maximum depth of flooding; (b) the period of flooding: and (c) the water-table, which in turn is dependent on the river level. He ruled out water-table as a water-slope factor affecting plant distribution, because the boundary between the communities is quite distinct. If water-table were involved there would be little or no difference in the level at which each community occurs, and thus no clear boundary would exist. Also he found the period of flooding was not correlated with the boundary of these communities because the water surface during the period of his survey (10 April - 3 May 1952) did not coincide with the topography of the boundary. The maximum depth of flooding, on the other hand, was parallel to the boundary and appears to be the major factor determining this boundary between shallow- and deep-flooded communities. His levelling data indicated that sites where the annual depth of flooding does not exceed 130 cm for 10 days, or 118 cm for 30 days are ideal for shallow-flooded communities. Conversely, sites flooding in excess of 130 cm will only support deep-flooded communities.

Within the shallow-flooded communities he noted that the proportion of *Phragmites* increased going away from the rivers. In most cases the distribution of *Phragmites* depended on the depth of available water especially during the dry season. This in turn depends on the period of flooding, thus *Phragmites* occupies sites which are flooded for short periods and dry out to a greater depth. In deep-flooded species, distribution is more complex as it is not related to substrate level. *Vossia* and *E. scabra* are found in quiet water. Because papyrus was found both above and below the minimum levels of flooding, Sutcliffe (1957) concluded that its distribution was not as dependent on depth or duration of flooding as the other two deep-flooded species. He found that papyrus was restricted to sites where the depth of flooding (the difference between minimum and maximum water level during flood) is less than 150 cm. Greater levels can be tolerated by the other deep-flooded species such as *Vossia* until a range of 3 m is reached at which point open water prevails. The ability of *Vossia* to dominate deep-flooding sites, i.e., hydrologically unstable environments, was confirmed by Thompson (1985) who pointed out that it is reported from deep-flooding areas in Sudan, Chad, West African and East African rivers, Zaire and Zambia.

Table 10: Comparison of two floodplains (based on Thompson's UNDP review, 1974).

1.	Floodplain:	White Nile Sudd region	Okavango Delta,
2.	Local name:	Toiche	Molapo
3.	Flooding and local climate:	4-5 month lag peak rainfall in Uganda and maximum flooding in toiche. Maximum precipitation in region coincides with peak floods and low PE.	5 month lag between peak rainfall in Angola and maximum flooding in molapo. Maximum precipitation occurs during low water and peak PE.
4.	Flooding sequence:	Flooding caused by water level in main channels overtopping natural levées.	Flooding caused by overtopping of natural levées.
5.	Grasses in floodplain:	*Vetiveria nigritana* *Sporobolus pyramidalis* *Sorghum lanceolatum* *Paspalum scrobiculatum* *Setaria anceps* *Oryza longistaminata* *Loudetia superba*	*V. nigritana* *Sporobolus sp.* *Sorghum sp.* *Paspalum sp.* *Setaria sphacelata* *Oryza sp.* *Cymbogon plerinodes* *Digitaria eriantha* *Echinochloa scabra*
6.	Wildlife:	Many birds and smaller animals. Sitatunga, Lechwe, crocodile and hippopotamus still found.	Many birds and smaller animals. Sitatunga, Lechwe, crocodile and hippopotamus evident.
7.	Fisheries (m tonnes yr^{1}):	**	400
8.	Land use and human activity:	500,000 people and 700,000 cattle associated with region. Considerable use made of toiches for grazing promoted by burning.	12,000 people and 130,000 cattle in and around delta. Natural crown fires probably common, but otherwise burning is only practised within swamp areas for benefit of hunters and tourists .

Sutcliffe (1957), by a series levelling and surveying measurements was able to explain the distribution of emergent vegetation on the basis of maximum depth and range of flooding. His explanation is much simpler in concept and operation and is more consistent with available data than earlier explanations based solely on depth and duration of flooding. and therefore is more appealing His general results were recently confirmed by the Mefit-Babtie study of the Sudd region (Anon., 1983).

** Presently being assessed (long term study underway)

What is needed now is a more detailed and experimental approach which will distinguish between floodplain species using some system based on water relations. We also need to know more about the site preference of specific floodplain species, especially those floodplain grasses which were not included in this early work.

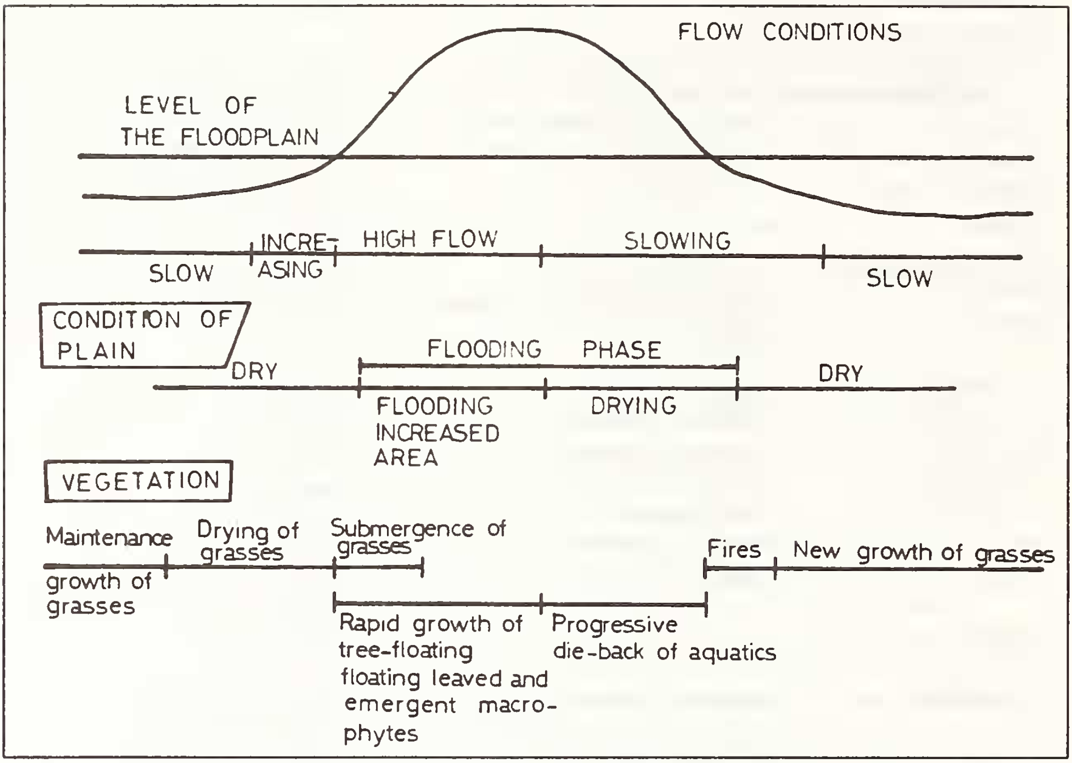

Figure 15. Summary diagram of floodplain cycle (modified from Welcomme, 1979)

CONCLUSIONS

Floodplains under normal conditions

The most impressive aspect of floodplains under normal conditions is the integration of physical and biological components within the system. Welcomme (1979) commented on this integration: "The traditional integrations of biological and human activities which make up the ecology of the floodplain river can only work if there is a community of micro-organisms. plants and animals which are adapted to the particular frequency of the environmental event which is fluctuating—in this case the flood."

Along large African floodplains the seasonal progression of events is similar. Thus, two examples north and south of The Equator, The White Nile Sudd (Figs. 4 & 14) and the Okavango delta (Fig. 10), although separated by 23-29 degrees of latitude follow similar cycles (Table 10). Fires occur in both and result in a fast recycle of ash nutrients but in a loss of volatile nutrients such as Nitrogen and Sulphur. The annual cycle shown diagrammatically in Figure 15 reflects a very productive system that is under a series of complex control mechanisms. However, because of their high rate of natural production, floodplains are attractive to developers and in many places in Africa, floodplains are being brought under management.

Floodplains under management

Welcomme (1979) gives many examples where water regulation, especially flood control, has allowed productive irrigation and fish farming to take place within floodplains. This is especially true in West Africa. In the closing section of this paper, I would like to look not at these well-known examples, but at some different cases, especially among major floodplains which have been put under stress as a result of river basin development. The subsequent results provide us with a valuable experience from which many African countries can benefit.

The most publicized example of floodplain management in Africa is the enormous scheme which was started in the southern Sudan to conserve water by canalization of the main flow through the Sudd region on the White Nile. At present the scheme has been halted due to political disturbances in the south of the country.

However, an ecological impact assessment was completed (Anon. 1983), and this outlined the major effects to be expected on completion of the canal. The basic options for management in this case will rest on future discharge levels in the White Nile itself. The canal can be operated either at high discharge levels such as have occurred since 1961 or at lower discharge levels such as occurred prior to 1961. Examples of both cases are shown in Fig. 16, and the resulting decrease in swamp and floodplain area is shown in Table 11. Under the best possible conditions, that is with river discharge levels remaining as high as they are now (in the 1980's-90's), the effects would be as follows:

1. The small lakes within the permanent wetlands will become shallower and susceptible to encroachment by vegetation. These lakes in the southern area of the Sudd will still remain permanent, however in the eastern area many will shrink in size and many will disappear;

2 Because of the decrease in turbidity of incoming water and the lower water depths that will occur, the growth of submerged vegetation will be encouraged along the banks and on the bed of the rivers flowing through the region. This will increase the retention of nutrients, but it will also encourage the growth of floating aquatic vegetation, such as water hyacinth (*E. crassipes*) and *Vossia* grass (V. *cuspidata*);

3. The aquatic grass *Vossia* will increase considerably because of its tolerance to deep-flooding sites. It will overgrow open water in those areas subject to falling water levels. This will create blockages in the main channels of the Sudd. Such blockages do not occur at present because steamer traffic keeps the channels open. With the diversion of this traffic into the canal the blockages by *Vossia* would be significant;

4. The area covered by Papyrus and *Typha* would be reduced because of contraction in their habitats. but as these permanent swamp types recede, their place will be taken by *Oryza*. The seasonally-flooded grasslands will also retreat and their place will be taken by grasses belonging to the genera *Sporobolus* and *Hyparrhenia*;

5. There would be little effect on present day fishing grounds and fish stocks, because at present these are very much underutilized. With the increased growth of floating vegetation, channel blockage will occur and this will cause interference in the access of barges to the fish collecting centres. It will also cause interference to the access of canoes into some of the fishing grounds. These effects can be mitigated as the fishing resources will still be more than adequate. The canal may even improve fishing effort because of the increased communication and travel to markets outside the affected region.

All of these effects may become more adverse if the effect of the canal is coupled with a fall in river discharge. If discharge levels decrease to those observed prior to 1961, the floodplain area will be so reduced (Fig. 16D) that many of the floodplain lakes would be lost and thus fish populations would decline. In that case significant socio-economic problems would certainly arise.

Another case in Africa is that of the Kafue flats (Fig. 17). Prior to the construction of the Kafue Gorge dam, the Kafue flats showed a classic floodplain profile (Fig. 17) and function. They had a gentle slope progressing from west to east with a loss of only 6 m elevation over 193 km. The soils in the flats are impervious clays. The Kafue river channel meanders over the flats and divides into occasional branches.

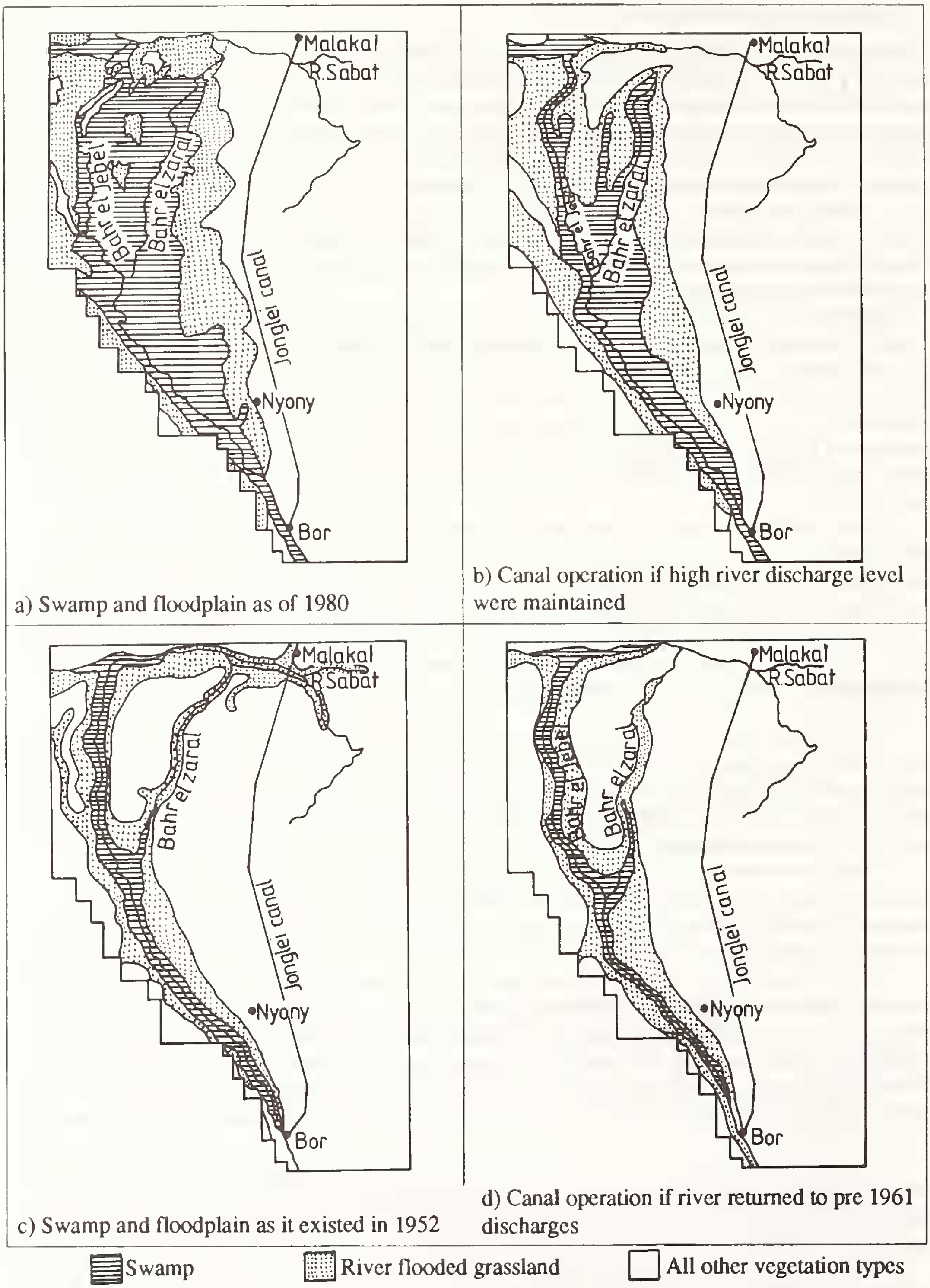

Figure 16. Comparison of swamp and floodplain during high water conditions on the Nile in 1980 and low water conditions (1953). The projected effects of the Jonglai Canal are shown (after Anon, 1983).

Table 11: Estimated effects of the Jonglei Canal on areas of flooding in the Sudd region (after Anon. 1983). When in operation the canal will divert 20 million m³ per day. Data from Mefit-Babtie study (1983)

	swamp km²	area of decrease %	floodplain km²	area of decrease %
No canal, estimated areas in 1980	16,357	—	15,476	
Operational canal, river remains at high discharge level	12,251	25.1	13,239	14.5
Operational canal, river returns to pre-1961 discharge level	3,688	77.5	7,624	50.7

The main river is bordered by natural levées so that when the river is running full, the water in the channel may be a metre higher than the surrounding land. Eventual overtopping of levées, flooding, subsequent natural drainage and drying completed the annual cycle (White, 1973).

The aquatic vegetation at Kafue flats is found within five general communities:

a) open water bodies up to 8m deep;
b) lagoons and river edges flooding to 4-6 m supporting an association of *V. cuspidata. E. pyramidalis, E. scabra, Leersia hexandra* and *C. papyrus*;
c) flooded grassland, 1.5-6m depth dominated by *O. longistaminata*.
d) shallow flooded grassland and levées with flooding depths of 0.25-25cm. Here tussock floodplain grasses occur such as *Vetivaria nigritana* and *Setaria avettae*; and finally
e) floodplain marginal regions supporting a grass cover of *Hyparrhenia rufa, Panicum coloratum, V. nigritana* and *Setaria sphacelata.*

Two dams were planned in order to achieve control over the Kafue river (Fig. 17). The first, Kafue Gorge dam would dam the river below the flats and would impound enough water to allow hydropower production during the subsequent four years until a second dam could be erected upstream above the flats (Fig. 17). This dam (the Itezhitezhi dam) would provide enough control over the whole river and floodplain system so that annual flooding-drying cycles could still be achieved within the floodplain. However, there would be a four year period between construction of the dams, during which time 2,000 km of floodplain would be inundated. This region to be inundated supported an *Oryza* floodplain grassland, where the principal species normally produced enough new growth each year to keep pace with the rising flood. The tips of the leaves and the inflorescence of *Oryza* must be maintained above the water level or it will die back. White (1973) predicted that four years of inundation would distrupt the normal cycle and that over such a long period death and decomposition of *Oryza* would result. He also cautioned that the open water expanse would be taken over by sudd-forming species with the result that the floodplain species would later require a very long period to be re-established.

White (1973) recommended that as much of the annual flooding-drying cycle of the floodplains be maintained as possible over the 4-year period. Subsequently, the first dam was closed in 1972 and it was decided to maintain the floodplain cycles as much as possible. However,during the dry season in 1973 the Kafue River receded to one of its lowest recorded levels. The floodplain drained except for large lagoons, and the whole region was burned. Because of the expected increase in demand for water following this drought, and the need to have a larger storage for the subsequent year, it was decided to store more water. Thus, following the 1973-74 rains, the storage level was allowed to rise 1.2 m above normal. As a result 2,200 km of the floodplain was flooded (Magadza, 1977). The *Oryza* grass died off and a rapid growth occurred of sudd-forming species such as *V. cuspidata* in shallow water, and *Aeschynomene elaphroxylon* in open water.

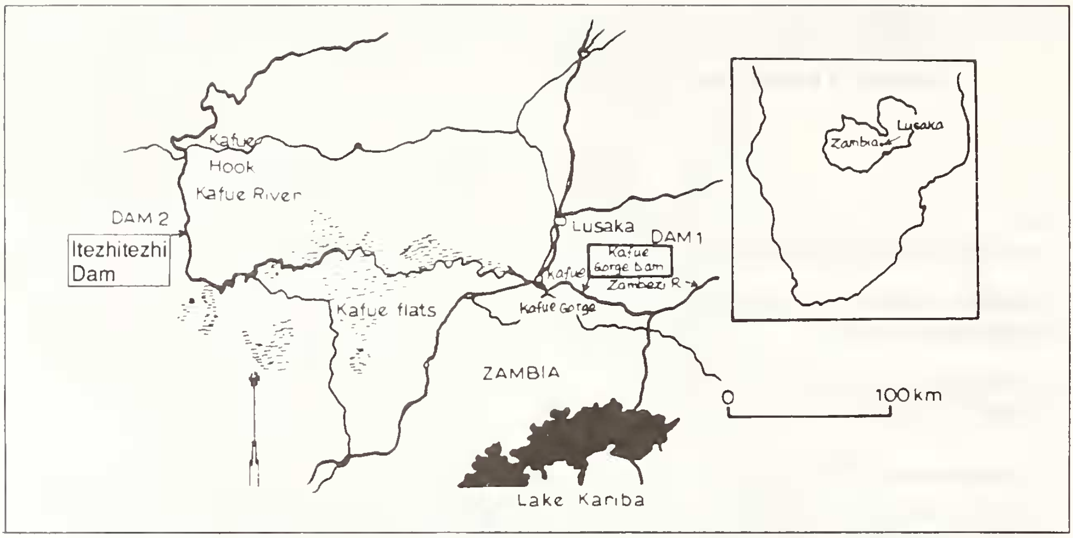

Figure 17. Kafue river with the floodplain, Kafue flats, and site of new dams:
1. Kafue Gorge dam
2. Itezhitezhi dam (after White, 1973)

The second dam was finally closed in 1977, with the result that the flooded area became smaller during the peak wet season, but during the dry season the inundated region remained permanently flooded (Werger & Ellenbroek, 1980). These effects were not predicted by the early models of the dam operations (White, 1973). In addition, the second dam developed structural faults due to geological activity and subsequently had to be drained. At present over 40% of the original Kafue flats floodplain still remains inundated with little hope of any change in the future.

Further downstream the Kafue enters the Zambezi which then flows east to the Indian Ocean. The Zambezi (at this point the mid-Zambezi) is dammed at Cabora Bassa in Mozambique and at Kariba between Zimbabwe and Zambia. Along a 100km stretch of the river between the two dams the Zambezi floodplain lies inside the Mana Pools Game Reserve (Fig. 18). In this floodplain (as in the Kafue flats) one typically finds *Oryza* grassland in the depressions and *A. albida* trees along the levées (Guy, 1977). This floodplain is of great importance to local wildlife during the dry season, it is the main grazing area of the mid-Zambezi Valley (Attwell, 1970). The whole floodplain region was earlier dramatically affected by the construction and operation of the Kariba dam in 1958. Since that time:

a) lesser amounts of silt have been deposited (most being trapped by the dam);
b) lower level of flooding prevails resulting in a lack of natural flooding; and
c) out-of-season low volume floods are common.

The terrestrial vegetation within the reserve is undergoing changes related to the changes in animal movement which in turn are caused by the changes in floodplain function. In the floodplain, even though there is still inadequate flooding, there is some evidence of colonization by *A. albida* on sandbanks and levées and regrowth of floodplain grasses, e.g. *Oryza* and *Setaria* species in the depressions. In other words, the floodplain vegetation is being re-established. but with much difficulty (Attwell, 1970).

It has recently been proposed that a third dam be built mid-way between Kariba and Cabora Bassa, at Mpata Gorge (Fig. 18). This dam would inundate all of the riverine stands of *A. albida* and the *Oryza* grasslands mentioned above. In other words, it would eliminate the floodplain in this part of the mid-Zambezi (Muller & Pope 1982).

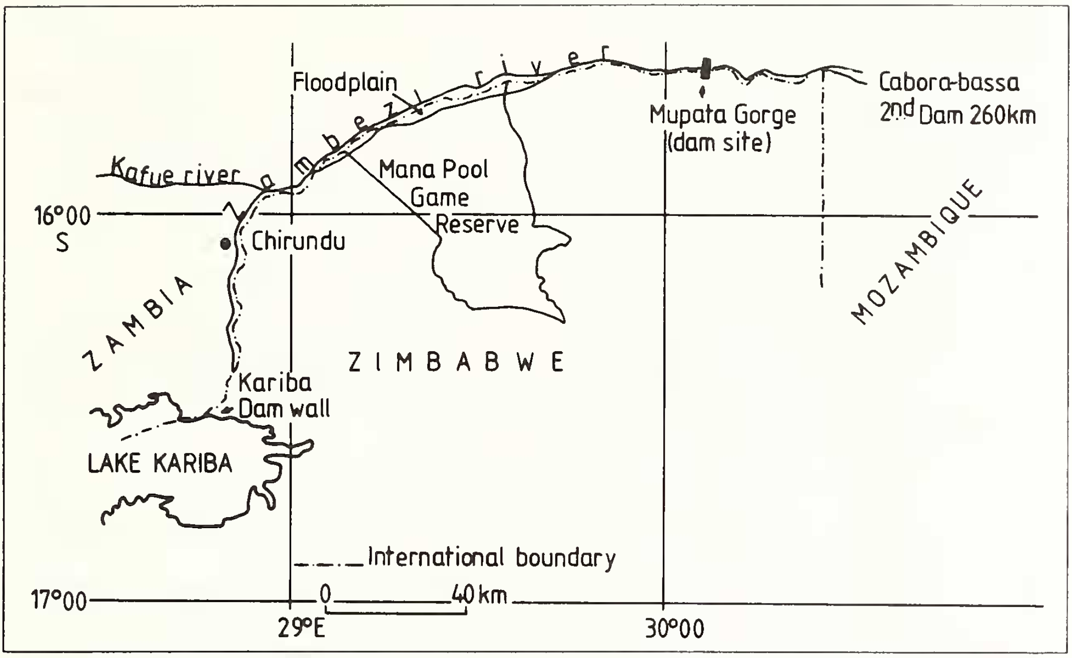

Figure 18. Zambezi floodplain downstream from Lake Kariba showing the Mupata Gorge (after Atwell, 1970)

The question now arises of whether or not any of the floodplains along the Kafue and Zambezi rivers will survive such development. Are there any development alternatives? In the case of the Kafue flats, even if the Itezhitezhi dam is put back into operation and even if it is operated in tandem with the Kafue Gorge dam, the floodplains may still not survive. The floodplain here needs an annual, 'close-to normal', flood-dry cycle. If this is to be achieved the two dams must be closely regulated in a careful, regular fashion which based on past experience, is obviously difficult to achieve.

In the case of the mid-Zambezi floodplains, there is an alternative to the Mpata dam, that is to utilize another site located in a gorge on the Upper Zambezi, 35 km below Victoria Falls. The reservoir created by this dam (Batoka Gorge dam) would be confined within the deep gorge and would have minimal impact on any existing floodplain and on Victoria Falls. Based on past experience, it would seem that the choice of this site would be a much better alternative than those management schemes that could result in the complete elimination of a valuable natural resource, the Mana Pools floodplain.

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